PLASMA PHYSICS IN PLANETARY AND SOLAR ENVIRONMENTS

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Submitted by Ira B Bernstein
Ira B. Bernstein
Principal Investigator

J L Hirshfield
J. L. Hirshfield
Principal Investigator

[redacted]

Yale University
New Haven, Connecticut
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During the period August 1, 1965 - January 31, 1966, theoretical and experimental effort under this grant has proceeded on a number of topics which relate to basic plasma processes in planetary and solar environments. Brief summaries of results to date are given below. The following personnel have been engaged in this work, with either partial or full stipend from this grant.

Faculty Members

Ira B. Bernstein, Professor of Applied Science
J. L. Hirshfield, Associate Professor of Applied Science
David E. Baldwin, Assistant Professor of Applied Science

Graduate Students

C. A. Buffalano
D. M. Henderson
D. W. Ignat
D. G. Polvani
J. M. Wachtel

Technical Support Personnel

F. Momparler, electronics
J. W. Olszyk, instrument maker
B. A. Kponou, secretary

An unofficial audit of this grant has shown that no funds were uncommitted as of January 31, 1966.

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SCIENTIFIC SUMMARIES

Stability of the Magnetopause

The investigations of the stability against fluctuations in the solar wind of the Chapman-Ferraro model of the magnetopause are being written up for publication. The manuscript will include the general formulation of the question of the stability of small motions, their interaction with the fluctuation spectrum, and solutions of the problem in various limiting cases. It is proposed to submit the manuscript for publication in the Journal of Geophysical Research.

Preliminary investigations are under way treating the problem via the ideal hydromagnetic fluid model. This is presumably far more realistic, allowing for an entrained magnetic field in the solar wind and a bow shock. Thus far, the linearized equations and boundary conditions have been derived.

Ira B. Bernstein and C.A. Buffalano

Radiation by Plasma Oscillations

A critical review of the extant theories of radiation by plasma oscillations is under way. It seems probable that a more sophisticated theory is possible which may lead to results of interest in interpreting radio signals seen during times of solar activity.

Ira B. Bernstein and David E. Baldwin

Radiation from the Two-Stream Instability

In the last semi-annual report, we discussed our results for the coupling of transverse electromagnetic radiation to unstable longitudinal electrostatic waves in a cold two-stream system. Even for homogeneous systems, and in the linearized theory, the transverse waves grow along with the longitudinal, provided the radiation direction is not along the relative streaming direction. Significant coupling to the transverse waves was found only in cases of highly energetic streams (i.e. $v^2/c^2 > 0.5$) and for fairly high density streams. This range of parameters suggested a possible connection with this theory and the origins of extra-thermal radio voice accompanying solar bursts.

One limitation to the analysis already made indicates that for the high non-zero electrical current implicit in the plasma model, a corresponding high static magnetic field is set up, whenever the transverse dimensions of the stream exceed several wavelengths. As the inclusion of this inhomogeneous magnetic field in the calculation introduces considerable complication into the analysis, we are presently looking at symmetrical systems with no net current.

D.W. Ignat, J.L. Hirshfield

Cyclotron Resonance Echoes - Collisionless

Our experimental efforts to observe single-pulse cyclotron resonance echoes have met with some success. In these experiments, a drifting cloud of 5 kev electrons is subjected to a short impulse of cyclotron resonance radiation at an "upstream" microwave cavity. At a second "downstream" cavity a strong macroscopic electric dipole moment P of the cloud is observed as a function fo the impulse strength. Attempts are now under way to compare the observations with the theoretical predictions:

a. Mono-energetic electrons

$$P^2(E) \propto N^2 J_1^2 \left[\left(\frac{\Omega_o^2 \ell L w}{Bc^2 u^2} \right) E \right]$$

b. A Maxwellian distribution

$$P^2(E) \propto \Theta N^2 \left[\frac{\Omega_o^2 \ell L}{Bc\langle u\rangle^2} \left(\frac{\theta}{mc^2} \right)^{\frac{1}{2}} E \right]^2 \exp\left\{ - \left[\frac{\Omega_o^2 \ell L}{Bc\langle u\rangle^2} \left(\frac{\theta}{mc^2} \right)^{\frac{1}{2}} E \right]^2 \right\}$$

Here

ℓ = cavity length

L = drift length

Ω_o = eB/m_o = electron cyclotron frequency

w = velocity component normal to $\underline{B}$.

u = velocity component along $\underline{B}$

Θ = temperature in energy units

E = impulsive electric field at frequency Ω_o

J. M. Wachtel and J. L. Hirshfield

Cyclotron Resonance Echoes - Collisional

Experiments are under way, but as yet giving no clear results, to observe one-pulse cyclotron echoes arising from non-linearities associated with collisional plasma processes, rather - as in the last topic discussed - than those associated with relativistic electrons. In this instance, the macroscopic dipole moment following an impulse E of duration T is

$$P \sim N E T \int_{0}^{\infty} dw w^2 \frac{\partial f_o}{\partial w} e^{-\nu(w)t}$$

where $f_o(w)$ is the electron distribution function and $\nu(w)$ is the velocity-dependent collision frequency. The radiated power is proportional to P^2. For ν = const., P^2 is a monotone decreasing function of time following the impulse. For variable ν, and for distributions $f_o(w)$ such that $\partial f_o/\partial w > 0$ over some range of w, then P^2 can peak up at some time following the impulse, and then decay. For example, with $f_o = \frac{1}{2\pi v} \delta(w-v)$ we find

$$P \sim N E T [2-tv\nu'(v)] e^{-\nu(v)t}$$

J. M. Wachtel and J. L. Hirshfield

Light Scattering from Ion Waves

The complete optical system for this experiment is assembled. Two types of plasmas have been tested for use in the experiments: a high power cw microwave discharge, and a "brush-cathode" discharge. The former has a high ratio of θ_e/θ_i and operates at low Argon pressure (~ 0.02 torr). The latter has θ_e/θ_i ~ 1 and operates at high Argon pressure (~ 1 torr). We would therefore expect the former to give lower overall signals than the latter, but that the former would have a scattering spectrum representative of weakly Landau-damped ion waves while the latter, the spectrum representative of collision damped ion waves. Construction of a "balanced-mixer" arrangement of photodiodes is under way as a means of increasing overall receiver sensitivity in this experiment.

D.M. Henderson, D.G. Polvani, J.L. Hirshfield